Defect-Related Properties of Polycrystalline Ceramic Scintillators

W. Rossner, F. Jermann
Siemens AG, Corporate Technology
81730 Munich, Germany

Polycrystalline ceramic scintillators with high optical quality up to full transparency are successfully applied to X-ray detectors for Computed Tomography (CT) medical imaging. They are full crystalline, like single crystals, but exhibit a microscopic granular structure of crystal domains (grains) separated by disordered regions (grain boundaries). The grain boundaries exhibit higher point defect concentrations compared to the bulk grains. These point defects introduce additional, sometimes negative effects not present in single crystals.

So far, $(Y,Gd)_2O_3:Eu^{3+}$, $Gd_2O_2S:Pr^{3+}$, $Gd_3Ga_5O_{12}:Cr^{3+}$ and $Y_3Al_5O_{12}:Ce^{3+}$ have been investigated, optimizing the scintillation properties to meet the requirements of CT. In general, light output, internal conversion efficiency and afterglow are strongly affected by the chemical composition and synthesis techniques. Light output and conversion efficiency are expected to be deteriorated by the existence of grain boundaries. There are indications that measured and simulated efficiencies achieve 80% of the theoretical limits /1/, as well as contrasting observations for YAG:Ce, where polycrystalline ceramics have 50% output compared to single crystals /2/. The implication of the grain boundaries will be discussed with reference to basic loss mechanisms.

A key property for applying polycrystalline ceramic scintillators for CT is a small afterglow effect. The afterglow behavior is commonly understood to be governed by point defects acting as charge carrier trapping centers. These trapping centers are related to anion vacancies or anion interstitials according to the intrinsic point defect chemistry of the corresponding compound. To illustrate this, the influence of Mg^{2+} doping on the afterglow of $(Y,Gd)_2O_3:Eu^{3+}$ ceramics is shown in Fig. 1. Supposing interstitial oxygen to be an efficient hole trap, the Mg addition decreases the oxygen interstitial concentration, resulting in a lower afterglow intensity.

In conclusion, the effect of grain boundary associated point defects on the optical and luminescence properties as well as the basic afterglow mechanisms are reviewed, focusing attention on the role of intrinsic and extrinsic point defects.

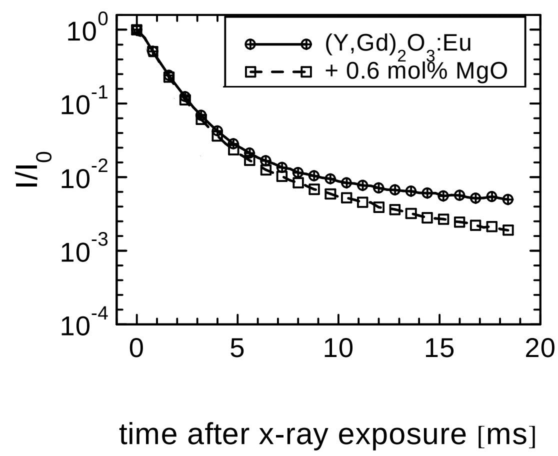

Figure 1: Influence of Mg addition (0.6 mol%) on the afterglow behavior of Eu-activated $(Y,Gd)_2O_3$ polycrystalline ceramics

References

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2. E. Zych, C. Brecher, H. Lingertat, Meeting of The Electrochemical Society 1997, Abstract No. 1520, p. 1748 (1997)